USER CARRYING CAPACITY FOR RIVER-RUNNING
THE COLORADO RIVER IN THE GRAND CANYON
F. Yates Bordon
Colorado River Research Program Final Report
TECHNICAL REPORT NO. 9

Colorado River Research Program

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Grand Canyon National Park
Grand Canyon, Arizona 86023

The Colorado River Research Program was initiated by the National Park Service in 1974 to secure scientific data to provide a factual basis for the development and the implementation of a plan for appropriate visitor-use of the Colorado River from Lee's Ferry to Grand Wash Cliffs and for the effective management of the natural and cultural resources within the Inner Canyons. The intensified research program consists of a series of interdisciplinary investigations that deal with the resources of the riparian and the aquatic zones and with the visitor-uses including river-running, camping, hiking, and sight-seeing of these resources, as well as the impact of use and upstream development upon canyon resources and visitor enjoyment.

Final reports that result from these studies will be reproduced in a series of Program Bulletins that will be supplemented by technical articles published as Program Contributions in scientific journals.

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USER CARRYING CAPACITY FOR RIVER-RUNNING THE COLORADO RIVER IN THE GRAND CANYON

Grand Canyon National Park
Arizona

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Chief Scientist
National Park Service
Washington, D.C.

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F. Yates Borden

Introduction

The popularity of river-running has grown immensely in the last decade, and the Colorado River in the Grand Canyon region has been one of the most attractive rivers for this recreation. User days have grown from about 5,000 in 1965, when flow was restored to the river after initially filling Lake Powell upstream, to the neighborhood of 100,000 user days. In 1972 the upper limit of user days was set at 106,000 by the National Park Service (NPS), otherwise it may have become larger.

Because of the rapid growth of demand for river-running, the expected questions have arisen. How much river-running can the riverine environment accommodate without detrimental impacts on it, and how should the system be managed? Prior to the last few years, an organized, comprehensive body of knowledge of the riverine environment did not exist. Although much has been written about the inner canyon and the river, it really constitutes only a sparse information base from which to make management decisions concerning use of the river. The picture is being changed by the various organized research projects now being conducted.

Objective

The object is to define in a numerical sense the visitor carrying capacity for river-running of the Colorado River in the Grand Canyon region. Visitor carrying capacity in this context is the level of river-runner use over a season that can be maintained from year to year without unacceptable impacts on the environment and that provides the visitors with an overall rewarding experience consistent with the nature of the environment.

To gain the objective, it is necessary first to define the system and then to analyze it. It is beyond the scope of the project to consider all possible aspects of the system and these limitations will be pointed out later on. The major emphasis of this study is on the physical and operational characteristics.

Background

River-running trips begin at Lees Ferry, Arizona, 15 miles downstream from Glen Canyon Dam and end in the upper reaches of Lake Mead. They traverse the full length of Marble Gorge and Grand Canyon and typically cover 225 to 280 miles in 6 to 18 days. Inflatable rafts of various types are used predominantly, with rigid-construction dories constituting a minority of craft. Rafts are often motorized with up to 55 hp outboard motors. These motors are used for control and speed. Non-powered craft are equipped with oars but use them mainly for control, relying on the river currents for propulsion. All trips are essentially self-contained and use undeveloped shoreline sites for overnight camping. Launching is limited to Lees Ferry and only a few sites exist where passengers can debark. The system is managed by the NPS, Grand Canyon National Park. However,

a number of federal agencies have jurisdiction over sections of the shoreline and river. Two kinds of groups run the river; commercial trips made by 21 private companies with concession contracts with the NPS, and private trips made by groups of qualified personnel and their friends having their own equipment.

All craft are launched at Lees Ferry and most are rigged there. Most trips load passengers for a complete canyon trip there, but shorter trips to Phantom Ranch (88 miles) are common where passengers who hike into Phantom Ranch to meet the trip are added or exchanged with those debarking there. Other common passenger exchange and debarkation points are Whitmore Wash (188 miles), Diamond Creek (226 miles), and points in Lake Mead (237-280 miles). Craft can be taken out and derigged at Diamond Creek or go to Lake Mead for this. The riverine part of Grand Canyon ends in the vicinity of Separation Canyon (240 miles). The canyon extends to Grand Wash Cliffs at mile 278, but the shoreline and river in this lower section have been greatly altered by Lake Mead water levels. This section is also accessible for river traffic and shoreline camping by Lake Mead users. For these reasons, the carrying capacity determination will be made only to Separation Canyon from Lees Ferry.

River flows are controlled for hydroelectric power generation by the Bureau of Reclamation at Glen Canyon Dam. They fluctuate daily but are generally high enough each day for river-running from May through October. Off-season flows allowing increased water storage in Lake Powell, combined with undesirable temperature and weather, limit the river-running season to the 6 months from November through April, but in view of the stated factors, it cannot be considered routine. Carrying capacity will therefore be based on a nominal 6-month season from May through October.

Fundamental Considerations of the Activity, Resource, Policy, and Management

The experience of river-running can be partitioned into five dimensions. The first two are visual and aural. The well-documented and reproduced sights need no further elucidation here. The aural dimension, though not so well documented, has not been overlooked; just subordinated in the presence of the visual dimension. The key feature is the extremely low background noise level, or the quiet and stillness of the canyon as authors refer to it. The natural sounds of wind, water, and wildlife, which range from quiet to very loud, all stand out prominently against the nearly noiseless background. The third dimension is one of adventure--composed of the white-water challenges, hiking and similar experiences, and open-air living in a wilderness environment. The fourth dimension is sociological and possibly the least contemplated by the visitor prior to the first river trip. The sociological dimension can be stated succinctly as the impact on river-runners of living for an extended period in close personal proximity within a fairly small group almost completely isolated from other humanity, including other parties of runners. The last dimension is the wilderness or natural environment itself; Grand Canyon, in its extent from Marble Gorge to Lake Mead, forms a perspective largely undiminished from its natural state by man's impact and strikingly emphasizes various natural phenomena.

These five dimensions existed at their peaks in the early days of river-running but, particularly within the last decade, each dimension has been compromised or threatened in many ways. The threat of hydroelectric dams, the noise and sight of low-flying airplanes penetrating the wilderness domain, the incessant noise of outboard

motors on river rafts, and congestion of rafts and people are a few of the real or threatening impacts on the experience. The NPS cannot control all influences on the river-running experience but the ones it can must be controlled decisively. That is, the levels of experience in each of the five dimensions must be evaluated and then attainable levels established as targets for management of the system.

The problem is not as imposing as it initially appears. First, the river-running activity and experience must be compared with alternate available activities and experiences at this and alternate locations. The intent of the comparison is to identify the features of river-running on the Colorado River in the Grand Canyon region that are unique, outstanding, undistinguished, and so on. Then policy must be stated that will direct management to preserve the selected best features of the experience at attainable levels. It is well beyond the purview of this project to delve into these matters in great detail and the only reason, but a very important one, for even following this avenue is that policy is the basic definer of carrying capacity. Management is the next most important definer even though it has a more direct impact on the carrying capacity. Management, however, is the implementation of policy and is therefore limited by it. Why management has a more direct influence on carrying capacity than policy is that a general policy statement must be translated into specific operational procedures by management. For example, if policy states, say with substantiation, that river-running will be a solitary group activity, then management could carry this out by scheduling departures at intervals to minimize intergroup contact. This scheduling regime is that which specifically establishes the carrying capacity.

Policy then defines carrying capacity indirectly and in non-specific terms, whereas management defines carrying

capacity specifically by the manner in which policy is implemented. Alternate management strategies, all adhering to the same policy, may lead to different carrying capacities for the same system. If policy is addressed to maximizing present use of a system for a particular activity, then the appropriate management alternative can be chosen. For the river resource under consideration, river-running is essentially the sole activity, therefore the policy can direct management to optimize for this use. An unusual aspect of this activity for this resource is that it is almost the exclusive demand on the resource. Maximization of use, of course, must adhere to a variety of constraints, of which two general categories are universal and major to the NPS: environmental preservation and user satisfaction. Environmental preservation is a fundamental mandate of the NPS. User satisfaction encompasses the user experience-related factors as well as the sociological factors operating within and among user groups.

Where do non-experience-related factors enter the scheme? Environmental, physical, and operational factors, amongst many, furnish constraints on the carrying capacity. Suppose in the example, management asserts, with substantiation, that a solitary group experience can be achieved if groups camp at a distance of at least 1 mile and be out of sight and sound range of each other. If campsites occur less frequently than at 1-mile intervals or if continual use would cause unacceptable campsite degradation, then either of these physical and environmental factors is more limiting and thus reduces the carrying capacity below that which management would otherwise allow.

To summarize at this point, the function of policy is to define with substantiation the objectives for management vis-a-vis river-running. The function of management is to optimize the use by river-runners consistent with the

existent known constraints. User carrying capacity is definable according to policy and optimum management in this case, where optimum is taken as maximum use within the constraints.

A judiciously functioning regime is not static but has a dynamism that allows policy and management to change in response to internal and external changes. Internal changes recognized through feedback should sponsor corresponding changes in management or policy. In this way the river-running system can be refined and remain consistent with constraints that may change over time. External changes, such as a shift in general demand away from river-running because of a decrease in interest or discretionary income or an increase in fuel shortages, should have an influence on policy and management. In any case, the carrying capacity will likely change although maybe not to any dramatic magnitude.

Management operates within the constraints, but only for those that are recognized. It is the role of research to identify the constraints, preferably in order from the most important to the least important. In addition, it is the responsibility of research to evaluate and define the constraints in a form that can be employed by management. It is the responsibility of either research or management, or both conjointly, to monitor the river-running system to determine whether constraint values are valid and that the system in operation is actually adhering to the constraints.

Finally, before considering the system specifically, the concept of operational carrying capacity will be stated. Carrying capacity can be achieved under optimum management, but operational carrying capacity is the level that is achieved because of certain suboptimal management procedures. Operational carrying capacity cannot exceed the carrying capacity and may be the level chosen for operation of the system for reasons not defined by the constraints.

In other words, management itself may consciously impose constraints for justifiable reasons. For example, management may simply desire to have a buffer capacity to allow for unpredictable anomalies in the system's behavior.

How can the carrying capacity of the particular system of interest be defined? It has been stated that it is a function of policy as well as management, and is subject to change. It will be evaluated in the context of present general policy, practice, and management strategies, and their minor variants. The most lasting benefit of this evaluation may not be in the resultant numbers but in the scheme of doing it. It is certainly expected that at least refinements in the evaluation of the carrying capacity will take place as ongoing inner canyon research furnishes more information.

Evaluation of the Resource for the Activity

Consider the characteristics of this river-running experience in the framework of the five dimensions introduced earlier. An attempt at comparison with alternate experiences should certainly be in much greater depth than can be done here, but the groundwork must be laid in order to proceed.

In these evaluations, let not the reader construe that the Grand Canyon is being belittled. The Grand Canyon, as a totality, is a unique and supremely magnificient feature, but river-running exists there because of the river and not solely because of the canyon.

The Visual Dimension

The level of the visual dimension must be rated as outstanding, but not unique. Other picturesque, large canyon systems are easily accessible and river-running is certainly not the only way to see the Grand Canyon. Much more of the Grand Canyon and its associated canyons can be seen via river-running than by other means, but the difference is primarily of magnitude and perspective. There is much of the Grand Canyon that cannot be seen from the river that can be seen from the rims.

The Aural Dimension

The aural dimension at its present level is not unique nor outstanding considering the frequency of noise intrusions by outboard motors on river rafts, subsonic and supersonic airplane flights, and helicopters.

There is serious doubt whether noise from low-flying aircraft can be controlled. Helicopter noise could be controlled to the extent that flights could be limited to emergency needs. There is questionable need for scenic helicopter flights as long as scenic airplane flights are commonly available. Noise from outboard motors on rafts is another matter. For non-motorized craft, outboard motor noise occurs, as does the aircraft noise, at scattered intervals. It has the same impacts as the aircraft noise--those of distraction and intrusion in the wilderness environment. For motorized crafts, the outboard motor is incessant and its impact is to block out all but the loudest of natural sounds. Typical passengers on these trips suffer temporary hearing loss well after the motor stops and, therefore, are denied the aural dimension almost entirely (Thompson et al. 1974). This noise source is

controllable, and if it were curtailed or eliminated, the level of the aural dimension would rank overall as outstanding. It is not unique because many other localities and activities have outstanding aural characteristics.

The Adventure Dimension

For adventure, the activity in most aspects is unique. Duration is one unique aspect. It is not readily apparent that alternative activities in the Grand Canyon, or elsewhere, can routinely match the uninterrupted duration of the adventure in a wilderness setting presented by this activity. Duration is important in the adventure dimension. The induction period of a few days or so that is necessary for most people to purge themselves of the thoughts and concerns of their worlds temporarily left behind and to recreate in the literal sense makes duration important.

The white-water adventure is spectacular and unique. The river furnishes the greatest number and aggregate of largest rapids in the nation. White-water adventure must be measured not only on the basis of the magnitude of the white water, but in conjunction with the manner of negotiation of the white water, and the skills of the adventurers. Even though Crystal, Lava Falls, and Hermit Rapids, to mention just a few, are challenging to any of the craft used on the river, the level of adventure must rank higher for dories than for 30- to 40-foot pontoon rafts. In either case, passengers are not responsible for navigation of the craft, therefore, they need not be skilled. Auxiliary craft, such as kayaks, which are often carried along with the larger crafts, allow varied levels of skill and matching challenges to be exercised because of the large number and variety of rapids. The uniqueness of the

white-water adventure lies in the potential to offer a wide variety of white-water experiences to a broad spectrum of participants.

The Sociological Dimension

In the sociological context, group size and density are controlled by policy and management. The level of this dimension in terms of user social satisfaction is dependent upon how well policy and management can match the natural characteristics of the system with individual and group attitudes, responses, and behavior in this recreational environment. This must be done within the various other limitations that exist; for example, the activity must be done in groups as contrasted to single individuals and the groups must be large enough to meet the daily operational needs of the activity. It is a very difficult task to determine what level of user satisfaction exists and even what is a reasonable level to establish as a target. A further complicating factor is the influence of support personnel, such as boatmen and interpreters, on the user satisfaction. Therefore, for the sociological dimension, an evaluation of the existing or potential level cannot be done here except to say it is at least satisfactory to the point that user demand for the activity remains strong.

The Wilderness Dimension

The rating as wilderness is without question outstanding and unique. Although Glen Canyon Dam has effected a major change in the character of the river, the new characteristics are still generally in the realm of a wilderness

river. The river is essentially uncontaminated and its water potable. Tributary streams are sanitary with some exceptions, such as Kanab and Havasu Creeks. Although not sanitary, the exceptions do not have any other objectionable traits and are aesthetically appealing. The environment is essentially unlittered even in heavily used areas, and shows a minimum of recent human impact. The air quality is outstanding.

The uniqueness is that it is a wilderness composed of a desert environment in a rugged canyon system of great length with a river available for convenient transportation. There are few comparable wilderness areas that can be entered for extended periods by the general public.

A Consolidated Evaluation

At this point, the nature of the experience for the groups as a unit can be defined. In the context of a wilderness experience, a sense of remoteness and isolation is taken as one of the requirements. Therefore, solitary groups can be considered as the norm for the system.

In the evaluation an an environment, the strong and clear expression of past and present geologic phenomena that are well documented for the Grand Canyon region adds to the distinction. Visitors can be afforded the opportunity with skilled interpreters of gaining an on-site understanding of a wide range of geologic phenomena not otherwise obtainable. The Grand Canyon is unique in this respect and float trips give undoubtedly the best and most accessible perspective for geologic interpretation.

It is not any one dimension alone that accounts for the uniqueness of the overall river-running activity. It is in the aggregate of such high, simultaneously attainable levels in the visual, aural, adventure, and wilderness dimensions that makes the river-running activity truly unique. Further add to this the fact that age, strength, dexterity, and so on are not very relevant on the part of the visitor since participation in this activity does not require any special physical attributes, skills, or preparation. Any individual, even one who is well-below average in self-sufficiency, can participate.

A Policy for River-Running

On the basis of all of the attributes of the system, the core of a general policy can be established. Float trips on the Colorado River in the Grand Canyon region will be conducted to allow a broad spectrum of people to participate in an adventuresome, aesthetically outstanding wilderness experience of long duration. The general theme may be expanded into more specific policy statements as exemplified by the following:

1. The experience will be oriented to small, solitary groups.
2. Health and well-being will be supported at recommended national norms considering the general physical activity of the participants.
3. Safety on the river will be maintained at the same level as other similar water-related activities.
4. Safety on the land will be maintained at a level consistent with similar on-land wilderness activities.

5. Interspersed physical activities in addition to river-running will be on an optional basis and may include day hiking, swimming, caving, fishing, and rock climbing.
6. Propulsion of river-running craft will be primarily by river flow.
7. Each river-running group will be self-contained with the exception of sanitary waste disposal.
8. Camping will be done at designated sites.
9. Waters will be preserved at their present levels of purity.
10. Campsites and visited land features will be maintained in a state consistent with the wilderness environment and will be undeveloped.
11. Each group shall contain at least one skilled boatman and at least one skilled boatman per craft.
12. Each group shall contain at least one skilled boatman specifically knowledgeable of navigation on the river.
13. Each commercially organized group will contain at least one support personnel knowledgeable in the geology, history, and biotics of the environment.

A definition of policy is necessary as the basis for estimating the carrying capacity. These policy statements are not necessarily comprehensive but they encompass the major focal points of this study. The salient points of these statements are addressed to the health, well-being, and safety of participants; the nature of the activity; interpretation of the resources; and maintenance of the environment. These points are intended to define the activity to be consistent with the characteristics of the system presented earlier.

Carrying Capacity Parameters

User-Days and Users

The units of measure for the numeric value assigned to the carrying capacity will be in user-days defined in the following for the purposes of this study. A user-day is counted for each user for each day in the system. Technically, a user-day will be counted for each user for each overnight to avoid the problem of partial days at the beginning and ending of trips. User-days will be counted from the launch point at Lees Ferry to Separation Canyon (mile 238) or, say, 240 miles from the launch point.

Policy statements 11, 12, and 13 deal with the number of support personnel. In reference to carrying capacity, it is considered that carrying capacity includes all users, not just passengers. The carrying capacity is unchanged by the number of support personnel, but the number of visitors is reduced by one for each additional support person. Therefore, the minimum number of qualified support personnel must be set in order to maintain the safety and well-being of users and to be able to interpret the environment. In addition, NPS maintenance and monitoring personnel will be counted as users, as well as personnel on other special trips such as for research purposes.

The Season

The nominal 6-month season shall be represented as 26 weeks or 182 departure days. That means computations of carrying capacity will be based on all departures over 182 consecutive days. Occupancy in the system would be 182 days plus the number of days for the last trip to clear the system.

Group Sizes

In applying the concept of small solitary groups, the size range will be taken as from 8 to 40 persons. It is reasonable to expect groups in this small size range to form coherent, cohesive, sociological units in a short period of time with this expectation being the assumed basis for a satisfactory sociological experience. The proper size range has not been precisely defined as yet by sociological research. Although smaller groups are possible, the lower limit of 8 is reasonable in that a group smaller than that size would be barely viable on the river for operational and logistics reasons.

The concept of an upper bound on group size can be defined, but assigning a numeric value to it is difficult. The upper bound is reached whenever the natural environment and activity become simply the background for a sociological experience. A vast number of equal or superior backgrounds exist for such purposes. In this system, river-running as a recreational activity and its magnificent environment would be poorly served if they were to be relegated to a role of incidental support for a sociological experience. Assigning a numeric value to the upper bound for a group size is necessary in order to evaluate carrying capacity even though it cannot be done here on sociological grounds.

Forty will be taken as a reasonable upper bound. A group size larger than 40 can be split into two or more smaller groups of reasonable size. The larger pontoon rafts of present design can handle in the neighborhood of 20 people as an upper limit, thus making for two large rafts per group. Huser (1975) presents an extensive review of craft and rig designs used in a variety of river-running situations. In his review, the larger rigs of 28 to 37 feet are used almost exclusively by commercial trips

on the Colorado River in the Grand Canyon. Rafts of such large size are at or beyond the limit for furnishing an exciting white-water ride in his opinion, based on substantial experience and contacts with river-running boatmen. For the campsites on the Colorado River, mooring for more than two of these large rafts becomes a problem and, in addition, many of the campsites cannot accommodate groups even of this size (Weeden et al. 1975). Considering all of these factors, excluding the sociological factors, 40 is a reasonable upper bound. Therefore, the carrying capacity will be evaluated only at this and the smaller group sizes. These size limits of 8 to 40 are bounds within which some more or less centrally located group size would likely be optimum.

Group Spacing

The solitariness qualifier imposes a spacing between groups to minimize sight and sound contact. Using the Belknap (1969) map or the strip map supplement to the campsite inventory (Weeden et al. 1975), a minimum that is predominantly satisfactory for minimum visual contact is about 3 or 4 miles. For sound contact between non-motorized craft, the minimum spacing would be much less than 3 miles. Between two motorized parties, the distance could be very small since the local motor noise drowns out the noise of even other nearby motors. The minimum spacing between a motorized party and a non-motorized party is the same for the motorized party as it is for two motorized parties. But, for the non-motorized party, it is about 1.5 miles. Based on the Hamblin and Rigby (1968) number of 161 rapids in the distance of 240 miles from Lees Ferry to Separation Rapid, a rapid occurs at the average interval of 1.5 miles. Leopold (1969) states that rapids are fairly

evenly spaced at 1.6 miles in the Marble and Granite Gorge sections. The noise of the outboard motor is at least effectively muffled if a rapid separates that party from the non-motorized party, and a spacing of 1.5 miles on the average places a rapid between two parties. This is not always true because in sheer-walled sections of the inner canyon and in Marble Canyon, motor sound may reverberate for about 5 miles. This is a moot point anyway since motorized rafts travel faster than non-motorized craft. In any case, the most limiting constraint for crafts at the same speed is the sight constraint, so a minimum separation distance of 3 miles will be assumed. From Lees Ferry to Separation Canyon, if no other constraints were considered other than the maximum group size of 40 and the minimum spacing of 3 miles, the daily system capacity would be 80 groups and 3,200 people. Extended over a 182-day season, the carrying capacity would be 582,400 user-days or only about five to six times the total user-days according to recent NPS allowances. If the maximum group size were 30, then the corresponding number of user-days would be 436,800. Other constraints have not been considered, but no matter what influence they may have, the user-days cannot exceed those given here.

Daily Time Use

Health and well-being of users have inputs to offer in estimating the carrying capacity as well as formulating the management plan. Nutrition, rest, and physical activity shall be simultaneously considered and levels established to maintain the health and well-being of the users. Consider rest. A minimum of 8 available hours for sleep is necessary as a norm. Because of the scope of ages and constitutions of participants to be accommodated, a

minimum of 10 available hours for sleep would be more reasonable. In addition, a rest and relaxation period of, say, 3 hours, not including the evening meal, is reasonable. Sustained day-to-day physical activity, although not rigorous by athletic or manual labor standards, is substantially greater than the norm for routine everyday living and, in addition, it is in a typically hot environment, in which participants are continually exposed to the elements. The rest and relaxation period is needed for these reasons as well as to allow for participation in camp-related activities. Two of these hours can overlap the 10 available hours of sleep period.

Unloading the craft, setting up camp, and the evening meal can be rated at 2 hours. Morning activity, including the meal, breaking up camp, and loading the craft, rates an equivalent time. Therefore, the time available for traveling is approximately 9 hours as an upper limit. Allowing a 1-hour minimum for a lunch stop and an average of 3 hours per day for interest and rest stops, yields 5 hours for river travel. The management plan then can state that the time on the river shall not be planned to exceed 9 hours in any day and that the average transit time shall not exceed an average of 5 hours. The basis for all of these time constraints is fundamentally for the health and well-being of participants. Even the breaks in the river-running period serve the same function in that periodic relief stops are necessary, as are opportunities to freely move about. The confined space on the river-running craft makes this latter kind of stop a necessity.

Trip Progress

The river flows at approximately 4.2 miles per hour, according to Leopold (1969). Flow is faster in the rapids

but these have an inconsequential effect on the downstream progress of craft. Craft propelled downstream by the river flow at 4.2 miles per hour for 5 hours can progress about 21 miles a day. The minimum length of the trip from Lees Ferry to Separation Canyon would be 11 days. Considering only a half day of river-running at the start, each trip will use 11 days in a span of 12 days. Separation Canyon is not a debarkation point, but the time in days used to Diamond Creek for debarkation is the same. For Lake Mead debarkation, 1 to 2 additional days of floating would be required, assuming passengers are picked up by boat in the upper reaches of the lake, but these days are not counted in the carrying capacity. Each trip for a 40-person group consumes 440 user-days and for a 30-person group, 330 user-days.

Environmental Protection Constraints

Policy statements 7, 9, and 10 deal with the environmental impact of river-running and the maintenance of the wilderness aspects of the environment and of its features. Their effect on the carrying capacity is important in that, if implemented management procedures fail to avoid unacceptable degradation of the environment, either the procedures must be improved or carrying capacity further constrained. These environmentally related factors must be monitored to determine whether degradation during the season and from year to year is occurring and, if so, at what rate. The on-site sanitary waste disposal issue is of critical importance because neither the short-term, in measure of a few years, nor long-term effects are known at this time. Continual on-site disposal of these wastes may very well be the most limiting constraint in the future, but for this evaluation it will not be considered as a

constraint. At such time that it is, should widespread but not irreversible degradation be found, then the carrying capacity would have to be reduced to allow for natural recovery. Otherwise, maintenance and restoration would have to be increased to avoid decreasing the carrying capacity.

Safety on the land, statement 4 of the policy, has no influence on the river-running carrying capacity except for the possible dangers due to congestion at features of interest. It will be assumed that stopping at specific features of interest is optional and will not be done in cases where overcrowding would take place. In the event that, by voluntary actions, specific features become congested so as to cause danger, environmental degradation, or detrimental sociological effects, then, but only then, would carrying capacity have to be reduced in counteraction.

Constraints Imposed by Campsite Sizes and Locations

Campsite Distributions

Camping would be done at designated sites. Camping is only possible in a relatively few locations along the river. Most of the shoreline is unsuitable for camping, even under extreme circumstances. The inventory of campsites and their designations by Weeden et al. (1975) shows about 400 campsites exist but are unevenly distributed in size and location. In Figures 1 through 5, the distribution is shown for 20- and 30-mile river stretches and various campsite capacities. In the figures, each point is plotted at the number of campsites in the section length centered at the given mile number. For example, in Figure 1, the distribution of campsites of 20 or more camper capacity is

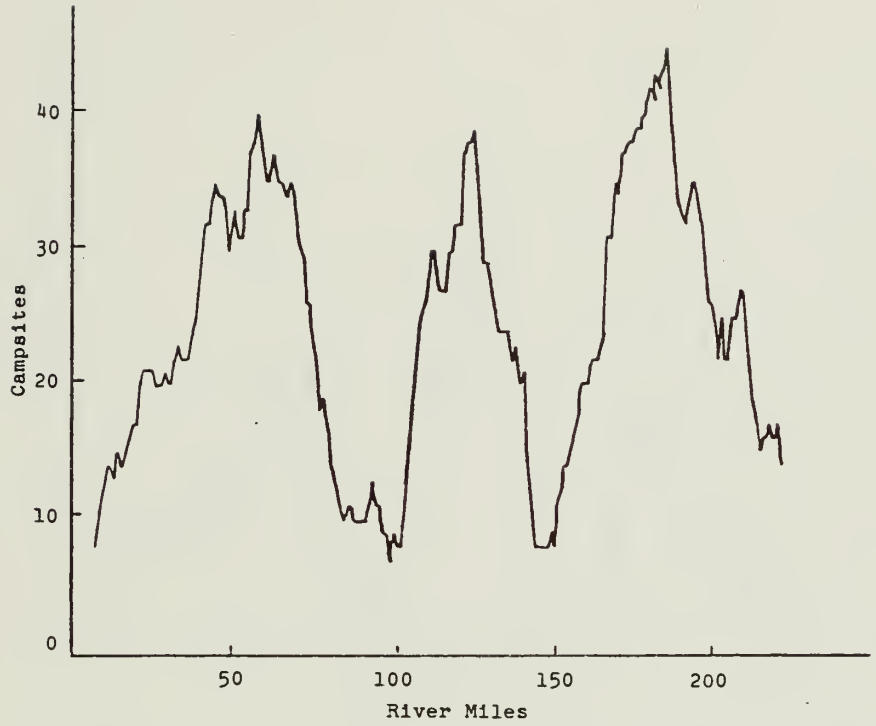

Figure 1. Number of campsites with a capacity of 20 or more along 20-mile sections of the Colorado River.

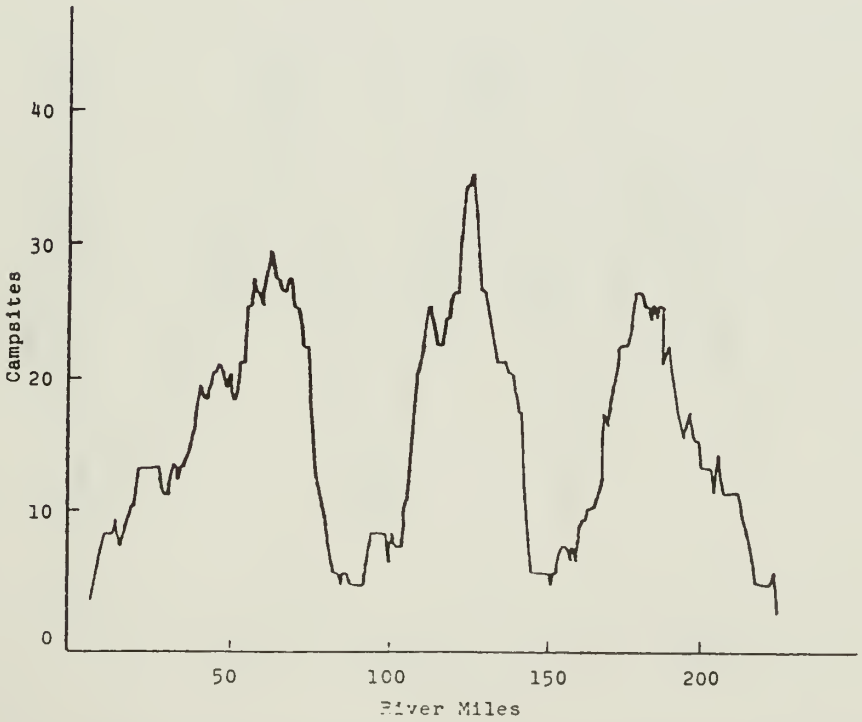

Figure 2. Number of campsites with a capacity of 30 or more along 20-mile sections of the Colorado River.

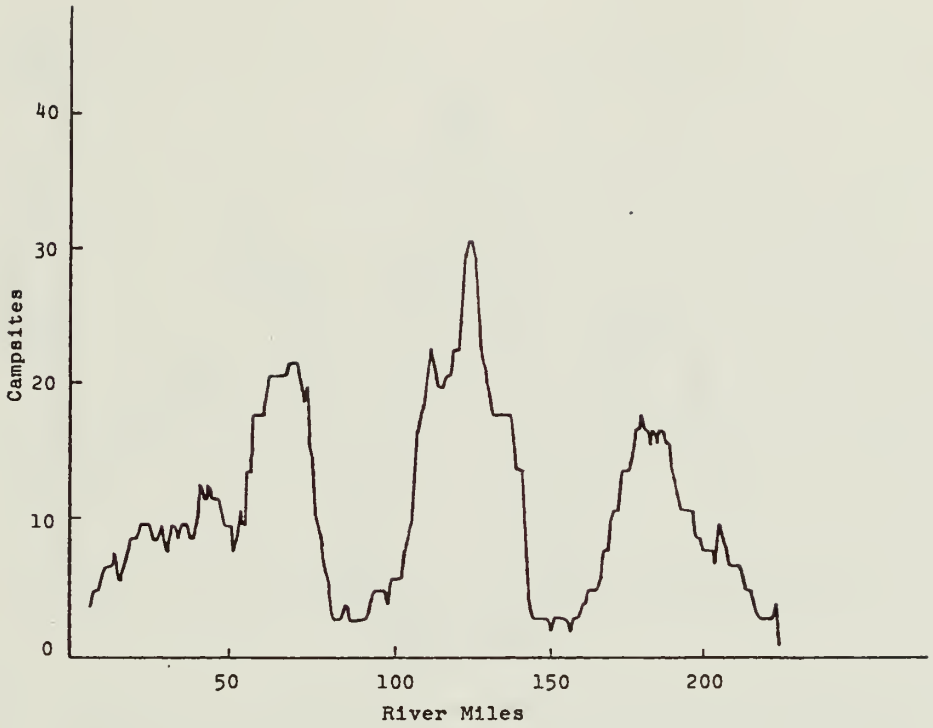

Figure 3. Number of campsites with a capacity of 40 or more along 20-mile sections of the Colorado River.

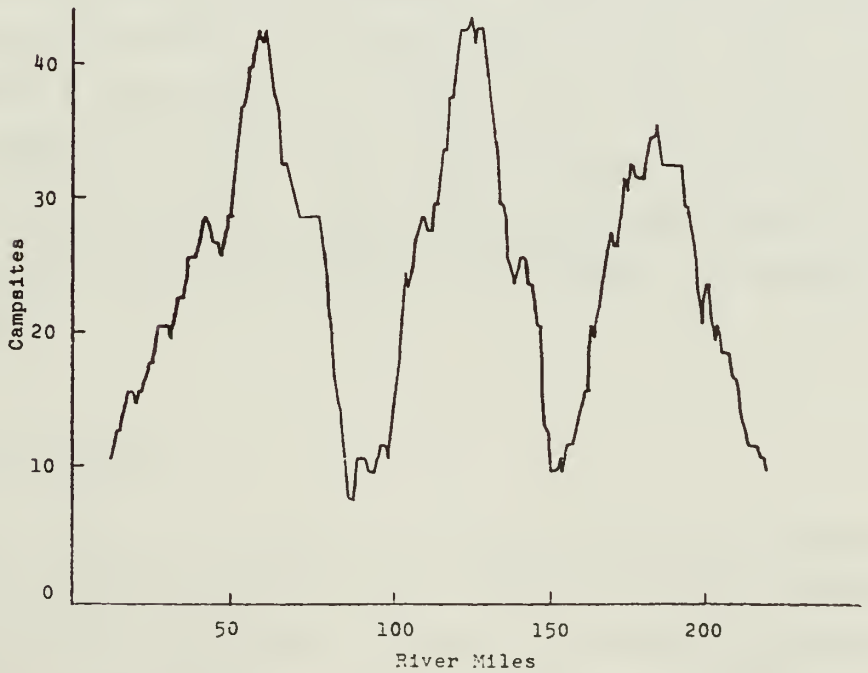

Figure 4. Number of campsites with a capacity of 30 or more along 30-mile sections of the Colorado River.

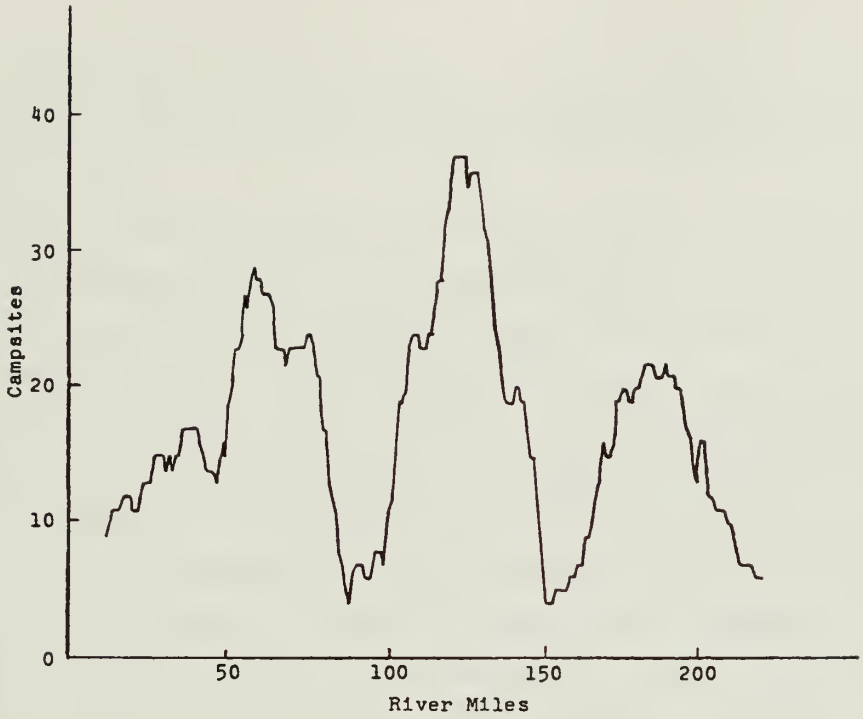

Figure 5. Number of campsites with a capacity of 40 or more along 30-mile sections of the Colorado River.

shown for 20-mile section lengths. The minimum number, seven, is at mile 98. It means that if river craft can only travel a distance of 20 miles in a day, then the maximum number of groups that can travel through that section in a day is seven. Thus the carrying capacity of the river is constrained to seven trip departures per day of some specific mix, not shown in the figure, of groups of 20 and larger.

Critical Sections

Four critical sections are apparent in the figures: immediately downriver from Lees Ferry (mile 0), Phantom Ranch (mile 88), Fishtail Canyon (mile 140), and Granite Park (mile 209). These critical stretches correspond to

easily identified features and will be referred to as Upper Marble Gorge, Granite Gorge, Muav Gorge, and Lower Granite Gorge.

In the 32-mile stretch from mile 139 to 171, the river resides predominantly in the lowest member of the Muav formation with but minor river level exposures of the Bright Angel shale. The bedding is nearly horizontal and unfaulted throughout the section, thus constituting the longest morphologically and lithologically uniform section at river contact. The Muav Formation in the section is deeper and is composed of more carbonates and less silt than in its exposure in Marble Gorge, thus forming a narrow gorge with sheer walls that frequently extend into the overlying Redwall Formation. The section is bounded by the Chikapanagi Fault at Fishtail Canyon (mile 139) and the Stairway-Willow Springs fault at Stairway and Mohawk Canyons (mile 171). The section is also characterized by a sparseness of campsites corresponding to one of the four critical sections in this regard. Hence, it will be referenced as the Muav Gorge.

Upper Marble Gorge

Tabulations are presented in Table 1 for campsites in the critical stretches using different section lengths. Consider groups of 20 or more. In Upper Marble Gorge, nine groups of 20 or more can be accommodated in the first 20 miles. The specific campsites, miles, and float times are given in Table 2 for the first 30 miles. Using 4.2 miles per hour as river velocity, one group of 40 and one of 20 would have to depart at least 9 hours before dark to allow 5 hours float time to 20 Mile and 19 Mile Wash Campsites, and 4 hours for lunch, dinner, unloading, and camp establishment. Two groups of 40 and one group of 20

Table 1. Campsite numbers according to campsite capacity and river section length for critical stretches.

	Upper Marble Gorge			Granite Gorge		
Section length (mi.)	20	30	50	20	30	50
Range (mi.)	0-20	0-30	0-50	94-114	88-118	75-125
Campsite Capacity						
8	1	3	3	2	2	3
10	0	3	7	4	5	8
12	0	0	0	2	5	5
15	0	0	7	2	5	7
20	3	5	7	0	1	4
25	0	0	3	0	3	3
30	1	4	6	2	3	6
35	0	0	0	0	0	0
40	5	9	18	6	10	27

Table 1.--Continued.

	Muav Gorge			Lower Granite Gorge		
Section length (mi.)	20	30	50	20	30	50
Range (mi.)	140-160	140-170	125-175	220-240	210-240	190-240
Campsite Capacity						
8	0	0	0	0	0	0
10	1	2	3	2	2	2
12	0	1	1	3	5	22
15	2	3	5	0	1	1
20	0	1	6	5	6	19
25	2	3	6	2	3	7
30	3	4	7	0	0	5
35	0	0	1	0	0	1
40	3	7	30	3	8	20

Table 2. Upper Marble Gorge campsites, capacities, distances, and float times for a 30-mile section.

Campsite	Location (mi.)	Camper Capacity	Distance (mi.)	Float Time (nearest hr.)
Cathedral Wash	R 2.7	30	2.7	1
Rock Fall	R 5.8	20	5.8	1
Jackass Creek	L 7.9	40	7.9	2
Badger Creek	R 7.9	40	7.9	2
House Rock Rapid	R 17.1	40	17.1	4
Upper 18 Mile Wash	L 18.2	20	18.2	4
Lower 18 Mile Wash	L 18.3	40	18.3	4
19 Mile Wash	L 19.3	20	19.3	5
20 Mile	L 20.0	40	20.0	5
21-1/2 Mile	L 21.5	30	21.5	5
22 Mile	R 21.8	30	21.8	5
(Unnamed)	L 22.3	30	22.3	5
(Unnamed)	L 22.4	40	22.4	5
23 Mile	L 23.2	40	23.2	6
25 Mile Rapid	L 24.9	20	24.9	6
Georgie's	L 26.2	40	26.2	6
Tiger Wash	L 26.7	20	26.7	6
Shinumo Canyon	L 29.2	40	29.2	7

would have to depart 7 hours before dark. A lunch stop would not be necessary. Two groups of 40 would have to depart 6 hours before dark, and a group of 30 and one of 20 would have to depart 4 hours before dark. Nine groups must depart in a time span of at least 5 hours, which averages to one about every half hour. A spacing of about 2 miles would result, which is tolerable for the first day considering these other limitations. Some logistics and congestion problems exist, however. First, controlled water flows from Glen Canyon Dam are low in the morning in this section of river, and Badger Creek Rapid is particularly difficult to negotiate in low water. Saturday and Sunday mornings have the lowest weekly flows and could make the rapids impassable. Two of the groups occupy campsites above Badger Creek Rapid and must go downriver the next day to at least 21-1/2 Mile and 22 Mile Campsites. Therefore, these campsites should not be used for Friday and Saturday departures because of weekend low water. A second problem exists because Jackass Creek and Badger Creek Campsites are directly across the river from one another, thus all but eliminating party privacy. Similarly, Upper and Lower 18 Mile Wash Campsites are connected by a short, very easily negotiated pathway and therefore lack mutual privacy. Furthermore, consider that every available campsite in this section would be used every day of a full departure schedule. Not only is there no flexibility, but the campsites would likely deteriorate rapidly under such heavy pressure. In the campsite inventory made in 1973 (Weeden et al. 1975), many of the sites visited in this section showed moderate to heavy use. For these reasons, 20 Mile and Lower 18 Mile Wash Campsites, each with a capacity of 40, should be used alternately; 19 Mile Wash and Upper 18 Mile Wash Campsites, each with a capacity of 20, should be used alternately; Jackass Creek and Badger Creek Campsites, each with a capacity of 40, should be used alternately; and

Cathedral Wash and Rock Fall Campsites should be assigned to auxiliary status. House Rock Rapid Campsite could be scheduled continuously but monitored constantly for degradation. Should degradation occur, use of it should be decreased. All of the campsites in this section should be frequently monitored and maintained since they will receive some of the heaviest use in the system. These limits on use will be considered as constraints on the carrying capacity. There are now three campsites with a capacity of 40 and one with a capacity of 20 for use every day. Only one other campsite exists in the stretch, Hot Na Na Wash Campsite with a capacity of 8. It will be added to those available for use but should be managed in the same way as House Rock Rapid Campsite. The aspects of scheduling will be investigated comprehensively in a later part of the report.

Granite Gorge

The next critical stretch, Granite Gorge from mile 94 to 114, has two campsites with a capacity of 30 and six with a capacity of 40, plus a number of small campsites. Pertinent data for these eight largest are shown in Table 3. Consider having a system where eight groups could depart daily. In this stretch, every campsite would have to be used every night and be very carefully scheduled for a nominal 20 miles a day progression. In addition, campsites used on the prior night would similarly have to be very carefully scheduled in order to allow adequate time for each group to get to its campsite in the 94-114 mile stretch. Table 3 shows that if all campsites are used, the nearest available campsite downriver ranges from 16 to 31 miles. An average of 23.4 miles must be covered in order to reach a campsite, which is reasonable, but

Table 3. Granite Gorge campsites, locations, distances, and float times in the 94-114 mile section.

Campsite	Location (mi.)	Campsite Capacity	Distance From Nearest Previous Night Campsite (mi.)[a]	Float Time From Nearest Previous Night Campsite (nearest hr.)[a]
96 Mile	L 95.9	30	21.6	5
100 Mile	L 99.5	40	24.0	6
107 Mile	R106.8	30	28.0	7
(Unnamed)	R107.5	40	31.0	7
(Unnamed)	L107.7	40	26.6	6
Bass Rapid	R107.9	40	20.8	5
Lower Bass	R108.3	40	19.0	5
(Unnamed)	R109.3	40	16.0	4

[a]Assumes all campsites in miles 94-114 were not available the previous night.

three of the groups must go more than 26 miles, which is not reasonable. The order of the groups must be maintained over the 2-day span. For the second night upriver and the next night downriver, the situation is much less critical because of the greater number of campsites within range. But, the inflexibility combined with the heavy use of these eight campsites and the eight nearest upriver campsites places this level of use above an upper bound on carrying capacity.

In coordination with the limitations of three size 40 groups, one of size 20, and one of size 8 for Upper Marble Gorge, the system could function reasonably well in the Granite Gorge. Four of the 8 larger campsites and one of the 10 smaller campsites would be used daily. The inflexibility would be relieved and the only problem would be in the likely degradation of campsites in this and the immediate upriver stretch. Three of the six 40 capacity campsites would be used daily if groups of that size and number were commonplace. In this stretch, if one were to choose between a maximum group size of 30 or 40, 30 would be the choice in order to distribute the load on campsites more uniformly. In the present system of operation with motorized rafts, the pressure is not as great because of the greater possible range of the motorized rafts. Even so, the 1973 inventory (Weeden et al. 1975) identified a number of the larger campsites in the Granite Gorge that were very heavily used and degraded. Therefore, in the Granite Gorge, campsites of 20 capacity and larger must be carefully monitored and maintained. Should they show overuse and cannot be suitably maintained, the carrying capacity would have to be correspondingly reduced.

Considering the Upper Marble and Granite Gorges together, the carrying capacity will be based on three groups of 40, one of 20, and one of 8 as the upper bound.

Muav Gorge

Next, consider the critical Muav Gorge stretch from mile 140 to 160. Refer to Tables 1 and 4. Three campsites are available for the group of 8 and five for a group of 20, which presents no problems. Three campsites of 40 capacity exist in this section, but five more of 40 capacity are upriver within 1.7 miles of the beginning of the stretch. There are no problems immediately upriver of the stretch because of the numerous campsites, but downriver the campsites are nearly as sparse as in the 140-160 mile stretch. Even so, the required float time to get to the next available 40 capacity campsite is, in every case, less than 5 hours even if every available one in the stretch were used daily. By including the five close upriver campsites, three groups of 40 can conveniently be accommodated in the eight available 40 capacity sites. Distribution of use can be done with some care and would result in a use level closely equivalent to the Upper Marble and Granite Gorges. The river section from, say, Deubendorff Rapid (mile 132) through mile 175 should be continuously monitored and maintained. Overuse and degradation of specific campsites in the section would not likely cause a reduction in carrying capacity. Instead, they can be closed temporarily or permanently and other campsites used. The problem of use is not so much caused by the sparseness of campsites but rather by the proximity of certain campsites to features of attraction, such as Deer Creek Falls and Havasu Canyon. The length of the section to be monitored and maintained is recommended for the combined reasons of few campsites and attractive local features.

Table 4. Muav Gorge campsites, locations, distances, and float times in the 140-160 mile section.

Campsite	Location (mi.)	Campsite Capacity	Distance To Nearest Next Night Campsite (mi.)	Float Time To Nearest Next Night Campsite (nearest hr.)[a]
Kanab Rapid	L143.3	30	20.6	5
Olo Canyon	L145.4	40	19.1	5
Art's Ledge	R151.6	40	14.9	4
(Unnamed)	L152.3	25	15.8	4
Sinyala Rapid	L153.8	30	19.0	5
(Unnamed)	R155.6	25	23.6	6
(Unnamed)	R158.6	30	15.7	4
(Unnamed)	L159.8	40	16.0	4

[a]Assumes all campsites from mile 140 through 160 are not available the next night.

Lower Granite Gorge

In conjunction with the limitations imposed by the upriver critical stretches, the Lower Granite Gorge stretch becomes non-critical. There are nine 40 capacity campsites within 20 miles upriver from one common debarkation point, Diamond Creek. There are an adequate number of smaller campsites above Diamond Creek for smaller groups.

The nominal end of the truly riverine environment is Separation Canyon. Thenceforth, the various levels of Lake Mead have a strong influence on the river and its shoreline. Campsites are scarce in some reaches and dense in others and depend upon the level of Lake Mead. The level of the lake has been changed from time to time and each change has presented a different situation for camping. Much of the shoreline is accessible by boats from Lake Mead and the exclusivity of use of specific camping places for float trips cannot be insured. There are problems confronting river-runners downriver from Separation Canyon but they do not influence the carrying capacity. Solution of these problems is well beyond the scope of this project and will not be undertaken.

Attractive Features and Congestion

Consider the possible limitations that special features might have on carrying capacity. In Table 5 are listed the majority of the features of interest and guidelines for the maximum number of parties possible and the reasonable period of use. The table should be revised appropriately by those more familiar with the features than the author. Furthermore, it should be revised from time to time according to use and impacts to insure that congestion does not occur and that the features do not suffer unacceptable

Table 5. Attractive features and estimated use limits.

Feature	Mile Number	Maximum Number of Groups at A Time	Maximum Time of Stay (hrs.)
Brown/Stanton Inscription	12	1	< 1
Silver Grotto	29	1	1
Vaseys Paradise	32	1	< 1
Redwall Cavern	33	1	1
Nautiloid Canyon	35	1	1
Buck Farm Canyon	41	1	2
President Harding Area	44	2	1
Nankoweap Ruins	53	3	1-2
Kwagunt Ruins	56	1	1
Little Colorado River	61	1-2	2-4
Comanche Creek	67	1	2
Tanner Mine (left)	69	> 2	1
Basalt Canyon and Tanner Mine (rt)	69	1	1-2
Cardenas Ruins	71	1	1-2
Unkar Ruins (left)	72	1	1
Unkar Ruins (rt)	72	1	1
Red Canyon and Hance Mine	76	1	1
Hance Rapid	76	> 3	
Asbestos Canyon	78	1	1
Clear Creek	84	1	1-4
Phantom Ranch	88	> 2	2
Monument Creek	93	1	2-4

Table 5.--Continued.

Feature	Mile Number	Maximum Number of Groups at A Time	Maximum Time of Stay (hrs.)
Hermit Creek	95	1	2-4
Boucher Creek	96	1	2-4
Crystal Rapid	98	> 3	1
Crystal Creek	98	1	1-2
Bass Area	107	2	1-3
Shinomu Creek	108	1	< 1
Mile 110 Ruins	110	1	1
Elves Chasm	116	2	1-2
Stone Creek	132	1	1-2
Tapeats Creek	133	2	5
Deer Creek Falls	136	1	2
Deer Creek Canyon	136	1	2-4
Kanab Creek	143	1	1-5
Matkatamiba Canyon	148	1	1-4
Havasu Creek	157	2	2-5
Cork Springs	158	1	1
Tuckup Canyon	164	1	1-3
National Canyon	166	1	1-3
Fern Glen	168	1	1-3
Lava Falls Rapid	179	> 3	1-2
Whitmore Pictograph	188	1	1
Spring Canyon	204	1	1-3
Granite Park	209	2	1-3

Table 5.--Continued.

Feature	Mile Number	Maximum Number of Groups at A Time	Maximum Time of Stay (hrs.)
Pumpkin Springs	212	1	1
Trail Canyon	219	1	1-3
220 Mile Canyon	220	1	1-3
Travertine Canyon	229	1	1
Travertine Falls	231	1	1
Bridge Canyon City	238	1-2	1
Separation Canyon	239	1	1

degradation. Some, such as Nankoweap Ruins, may have to be put off-limits until natural or artificial restoration occurs. Congestion defies the solitary group concept in addition to these other undesirable aspects. Congestion does occur too often at sites where the available area is too small for more than one party at a time. Deer Creek Falls and Travertine Canyon are two notable examples.

There are some places where congestion is not a problem nor undesirable. Hance, Crystal, and Lava Falls Rapids are three such places. Boatmen, as general practice for safety considerations, stop before entering severe rapids to determine a strategy for navigation. Very often they like to see how the rapids affect other craft during passage. It is, of course, a thrill for passengers to anticipate going through such violent white water and thereby adds to the experience for those not faint of heart. Some rapids with back eddies and mooring areas at their feet allow for passengers to watch other parties negotiate the white water and to take those once-in-a-lifetime pictures, sometimes at close range. A case in point is Lava Falls Rapid where the setting of the rapid seems to have been designed for spectators as well as participants. Contrary to the solitary, small group concept, congestion at sites such as these should not be discouraged and should be controlled only if necessary for safety reasons.

Regarding congestion and the visitation of specific features, the management plan should identify each of the popular features and establish visitation and use guidelines. A general rule should be established that any party that would otherwise violate the use constraint of a feature will either pass up the feature or wait for a party to leave before visitation. Should this fail to control congestion and overuse, the second alternative would be to schedule feature use for each trip before departure. Should

this fail, then the constraint must be introduced into the carrying capacity evaluation. Such a constraint would be to increase spacing between parties or put the feature off-limits. Increasing the spacing to, say, 8 miles would allow a party 1 hour at a feature and an hour's lead on the following party based on the average river flow of approximately 4 miles per hour. Such a constraint would reduce the total carrying capacity by one-half or more and should be considered only as a last resort.

Preliminary Carrying Capacity Results

Based on the campsite size and number distribution as the major constraint, the carrying capacity is three groups of 40, one of 20, and one of 8. These five groups will, on the average, occupy a 21-mile stretch of river or, on the average, have a 4.2-mile spacing. This is conformable to the 3-mile spacing recommended for the constraint of solitarity.

Every group can complete the trip through mile 240 by averaging 21 miles per day in 12 days using campsites in the 240-mile length for 11 nights. Carrying capacity can then be determined as follows: A total of 148 users may enter the system each day. For a season of 182 departure days, the total number of users entering for the season would be 26,936. Each entrant absorbs 11 user-days for a carrying capacity of 296,296 user-days. Five groups would have to be launched each day. Considering extremes, if the capacity per craft were 4, then 37 of these craft would have to be launched; or, if 20 per craft were possible, then 9 such craft would have to be launched. The actual number of craft would be somewhere between these extremes, likely around 16. The group size of 40 would

likely use crafts of moderate size, say, for 10 passengers. The group of 20 would use 2 to 3 crafts, and the party size of 8 would use 1 to 2 crafts. These numbers are not unreasonable for the embarkation and debarkation points and, if they are not within present manageable limits, major changes would not be required for increasing the limits. Debarkation at Diamond Creek will present a continuing sporadic problem because the access road frequently washes out in summer storms.

Scheduling

The carrying capacity is only realistic if the system could actually function at that level of use, and this requires that use could be scheduled satisfactorily. In arriving at the carrying capacity, among the constraining factors, scheduling was considered in a general way for the critical sections. In the following, a refined scheduling evaluation will be made, treating the whole system as a unit.

Definition of the Scheduling System

The attributes of simplicity and flexibility are of foremost importance in scheduling for this system. Scheduling procedures must be reasonably uncomplicated and easy to apply by managers and boatmen, not only on a trip-by-trip basis, but also day by day during trips. Flexibility is needed to conveniently allow for a variety of uncontrollable situations such as low water, upriver wind, and adverse weather to name a few. Of equal importance, flexibility must be attained in order for users and boatmen,

as their guides, to do what they want to do in their own time and where they want to do it with a minimum of interference by schedule restrictions. The ideal scheduling routine would be one that is transparent to the users; e.g., they do not recognize a schedule is being followed but feel their trip is operating with complete freedom. Users and boatmen, however, must be made aware that adhering to schedule requirements, no matter how unobtrusive, is important to insure other users of the same opportunity for enjoyment of the experience and to best maintain the environment for long-term use. Day-by-day scheduling for two kinds of trips, regular and irregular, will be undertaken. Regular trips are those that progress downriver at a nominal rate of about 20 miles a day; camp overnight for 11 nights, each night in a particular river stretch; and leave the system on the 12th day. Irregular trips are those for which significant departures are made from the regular pattern, such as trips in excess of 12 days.

The scheduling evaluation will presume that intergroup contacts be controlled by boatmen. The rigidity of an ordered progression downriver at a set minimum spacing is ruled out. First, intergroup contacts, which include passing, are operationally impossible to avoid. Furthermore, they are a necessity in some situations for boatmen to mutually adjust their plans for compatibility in campsite selection, feature visitation, etc. Assuming this would be the modus operandi for detailed scheduling, the scheduling regimen can retain a substantial measure of flexibility and simplicity. Intergroup spacing will also be deemed a function of the boatmen. Spacing cannot be scheduled and still allow for flexibility; it must be voluntarily adjusted en route. In fact, campsite locations in critical sections frequently prohibit maintenance of a minimum specified spacing.

In evaluating scheduling patterns for campsite assignments, ones were favored that most evenly distributed the number of times of use over campsites. The second criterion used to select patterns was overall evenness in spatial distribution for each night. That is, for a given river section in which all groups would be occupying campsites, patterns that gave the maximum spacing between groups were favored. As expected, the critical sections presented the greatest problems in scheduling, but the critical Granite and Muav Gorge sections present additional problems because the sections do not correspond with a single-day transit. In the Granite Gorge section, for example, some of the groups departing from Lees Ferry the same day spend the 5th night in the section, while the rest spend the 6th night there. In spite of these scheduling problems, only 6 of the 11 camping nights required campsite scheduling. For the other 5 nights, the selection of campsites would be up to the boatmen with only the following restrictions:

1. The campsite must have a capacity that equals or exceeds the total number of people in the group.
2. For regular trips, the campsite must be in the river section specified for the night.
3. The campsite must be out of sight and beyond easy access from other occupied campsites.
4. The campsite should be the greatest possible distance from other occupied campsites.
5. The campsite must not be restricted from river-runner use, such as those in proximity to Phantom Ranch.

These restrictions are used throughout the report and have been applied as well to the critical sections in developing the necessarily more-restrictive scheduling patterns for these sections.

Scheduling will be presented in the order of each day from departure. For each day, it will cover full-capacity scheduling for regular and irregular trips. Over- and undercapacity scheduling will subsequently be integrated with full-capacity scheduling. Five groups per day are involved and will be identified as follows:

1. one group, the size of which does not exceed 8 persons (S or S-group);
2. one group, the size of which does not exceed 20 persons (M or M-group); and
3. three groups, the size of which does not exceed 40 persons (L's or L-groups).

The groups are defined in this manner, instead of as small-sized, medium-sized, and large-sized, because a group of maximum size 8 could be scheduled as a small-, medium-, or large-sized group, and a group of 9 to 20 persons could be scheduled as a medium- or large-sized group.

Full-capacity scheduling represents all five groups departing on a departure day and each group composed of its maximum number of people. Under- and overcapacity scheduling can each occur in two ways. The number of departing trips may be other than five and the number in one or more of the groups may be other than the maximum.

Full-Capacity Scheduling

A vast number of campsite scheduling patterns exist for the river sections where patterns must be selected. To grasp an understanding of campsite scheduling patterns, refer to Table 6 where the basic set of 16 patterns for Upper Marble Gorge is shown. The evaluation of all possible patterns led to the general conclusion that all of the

Table 6. Basic scheduling patterns for Upper Marble Gorge.

Campsite Designation	Campsite Capacity	Patterns[a]							
		1	2	3	4	5	6	7	8
L 7.9[b]	40	L	L	L	L		L	ML	SML
R 7.9[b]	40								
L16.5	8	S	S	S	S	S		S	
R17.1	40	L	L	L		L	L	ML	SML
L18.2	20	M					SM		
L18.3	40		L		L	L		ML	SML
L19.3	20		M	M	M	M	SM		SM
L20.0	40	L		L	L	L	L	ML	SML

[a]S = small group designation, only S group can camp; M = medium group designation, only M group can camp; L = large group designation, only L group can camp; SM = small or medium groups can camp; ML = medium or large groups can camp; SML = 1 small, 1 medium, and 3 large groups must be allowed.

[b]Corresponding patterns using R7.9 instead of L7.9 exist and are denoted, where used, by a primed number of the corresponding pattern.

scheduling objectives could be met by condensing selected patterns to form a pair of patterns in each case where patterns were needed. In so doing, spatial and use distribution objectives could be met satisfactorily; but, more importantly, a very simple scheduling scheme could be achieved for regular and irregular trips. For each river section where scheduling patterns apply, members of the pair are labeled "odd" and "even." For a regular trip entering that section on an odd-numbered day of the month, the odd pattern is followed. The even pattern is followed for even-numbered days. Conversely, for any irregular trips entering the same section, the odd pattern is followed for even dates and vice versa. This rule applies in every case except for the day of departure when no distinction is made between regular and irregular trips. For that day, both kinds of trips, in aggregate, fall under the same pattern for the day. In this way, the overall carrying capacity constraints are met in that total departures and group size maxima per day are not violated. Use distribution is not affected in general because for every patterned-use campsite occupied by an irregular trip, a corresponding regular trip campsite is not occupied. The very safe assumption is made that on the average the same number of irregular trips arrive at a critical section on odd as on even dates. A restriction on irregular trips is that in critical sections, except by special pre-trip arrangement, a group may not stay at a campsite more than 1 day. Otherwise, conflicts with the regular trips would ensue.

Day 1 (Departure).--The first day must be patterned. The Upper Marble Gorge is most critically deficient in campsites. A number of conditions must be met by each group prior to departure, therefore, scheduling must be

flexible in order to function. Prior to departure, each trip must complete rigging and provisioning; passengers must arrive and be briefed on safety; passenger gear must be organized and stowed; and inspection must be made and clearance be obtained from the Park Ranger. In addition, low water flows are common during the morning, a number of which may be too low for passage through Badger Rapid. The hours of daylight nominally required to reach campsites are given in Table 7. All factors considered, timing is critical and trips must be allowed to depart as soon as possible when they are ready. The rule for scheduling is clearly that as each trip is ready, it departs for the farthest available campsite. The patterns are given in Table 7. These two patterns were chosen for their flexibility. Sixteen patterns are possible as shown in Table 6. Of these 16, 6 pairs were formed, as shown in Table 8, that would give the best use distribution; namely, 6 campsites used 50 percent of the time and 2 campsites used 100 percent of the time. Completely balanced use at 62.5 percent for all campsites is not possible because only one of L7.9 and R7.9, and one of L18.2 and L18.3 can be used at a time. The selected pair is 6 and 7'.

Consider how the schedule can function. The boatmen of each of the five departing groups must know and be able to identify the other groups leaving that day. This is important for all days on the river, not just for the departure day. For an odd-numbered day of the month, the first large group to leave will go to L20.0. If time and conditions permit, the boatmen may choose to go to L22.4. In this latter case, the decision must be made prior to departure so that L20.0 may be made available as an option to the next departing large group. The second large group ready to leave will go to R17.1 or to L20.0 if it is available. If L20.0 is selected by the boatmen, R17.1 is

Table 7. Day 1--departure day scheduling patterns.[a]

Campsite Designation	Campsite Name	Campsite Capacity	Odd Date Use	Even Date Use	Daylight Hrs. Needed[b]
L 7.9	Jackass Creek	40	L		5
R 7.9	Badger Creek	40		ML	5
L16.5	Hot Na Na Wash	8		S	8
R17.1	House Rock Rapid	40	L	ML	8
L18.2	Upper 18 Mile Wash	20	SM		8
L18.3	Lower 18 Mile Wash	40		ML	8
L19.3	19 Mile Wash	20	SM		9
L20.0	20 Mile	40	L	ML	9
L20.2	(Unnamed)	8		S[c]	9
L21.5	21-1/2 Mile	30	M[c]		9
L21.6	(Unnamed)	8	S[c]		9
R21.8	22 Mile	30		M[c]	9
L22.3	(Unnamed)	30	SM[d]		9
L22.4	(Unnamed)	40	L[c]		9
L22.6	(Unnamed)	10		S[d]	9
L23.2	23 Mile	40		L[c]	10
L24.9	25 Mile Rapid	20		SM[d]	10

[a]S = small group designation, only S group can camp; M = medium group designation, only M group can camp; L = large group designation, only L group can camp; SM = small or medium groups can camp; ML = medium or large groups can camp.

[b]Includes times for floating, lunch, dinner, unloading, and first-night camp establishment, but not for unanticipated delays such as low water at Badger Rapid.

[c]Primary alternative for early departures.

[d]Secondary alternative for early departures.

Table 8. Campsite use for pairs of basic scheduling patterns for Upper Marble Gorge.

Campsite Designation	Campsite Capacity	Pattern Combinations[a]					
		1 & 2'	1 & 4'	1 & 8'	2 & 6'	4 & 6'	6 & 7'
		percentage					
L 7.9	40	50	50	50	50	50	50
R 7.9	40	50	50	50	50	50	50
L16.5	8	100	100	50	50	50	50
R17.1	40	100	50	100	100	50	100
L18.2	20	50	50	50	50	50	50
L18.3	40	50	50	50	50	50	50
L19.3	20	50	50	50	100	100	50
L20.0	40	50	100	100	50	100	100

[a]Patterns by number are given in Table 6.

available for the last departing large group. If the small group is ready before the medium group, it goes to L19.3 or, by choice, to L21.6 or L22.3. The medium group then goes to L18.2 or to L19.3 if it is available.

Even under optimum circumstances, it is unlikely that a group could comfortably go further than 25 miles on the first day. For this reason, 25 miles will be taken as the upper limit for the day.

Irregular trips are treated as part of the regular schedule on departure day. Their irregularity does not occur until at least after the first day and, in fact, would be of no concern until the fourth day.

Day 2.--Scheduling for the second day is a very simple matter; an abundance of campsites exists. The mile limit beyond which to camp will be taken as 29, 1 day's average travel from the most upriver campsites routinely used; namely, at 7.9 miles. The only other restrictions are the general ones; do not camp in close proximity to other occupied campsites and camp only at a site that has an adequate specified capacity.

Irregular trips have no influence on scheduling for the second day of regular trips. Irregular trips must at least pass mile 20 on their second day in order to clear that section for following departures. If an irregular trip camps in the stretch from 20 to 25 miles and the date is odd, it must camp at even-date campsites and vice versa in accordance with the general rule for irregular trip scheduling.

Day 3.--Similar to the second day, there is only one specific scheduling restriction; but an important one--camp prior to Unkar Rapid, mile 72.5. One group from those 1

day ahead will likely be in the section below Unkar Rapid and above Nevills Rapid, mile 75.5. Beyond Nevills Rapid, campsites are sparse and scheduling is quite restrictive.

If a regular trip must pass Unkar Rapid on Day 3, it must follow the schedule for irregular trips on Day 4. Such a situation would occur if the last few campsites above Unkar Rapid were occupied. The passing of Unkar Rapid on Day 3 for a regular trip makes it immediately an irregular trip for that day. The trip can conveniently return to regular status on Day 4 or Day 5.

For irregular trips camping above Unkar Rapid, no special restrictions are imposed. When an irregular trip passes Unkar Rapid, however, it comes under the irregular trip scheduling applied to the regular trips on Day 4.

Day 4 and Day 5.--During the fourth and fifth days, the Granite Gorge critical section is encountered. The two days are considered together because campsite selection on Day 4 somewhat limits the selection on the following day for the medium and large groups. Campsite selections are simple for the one small group on these days, with four or five available for each day. The options are given in Table 9. Small groups may not choose any medium or large group campsites since they are in shorter supply.

Phantom Ranch and the transcanyon trails are within a few hours' travel from the Day 4 campsites and Day 5 campsites are all beyond this access point. Passenger debarkation and exchange can be done conveniently during Day 5. Camping must be done upriver from this point for the fourth day and downriver from it for the fifth day to avoid conflicts with trips 1 day ahead and behind.

The suggested scheduling patterns for large groups are shown in Table 10. The order of the three large trips should be maintained over the 2 days unless boatmen

Table 9. Day 4 and Day 5 campsite selections for small groups.

Day 4 Campsite Designations		Day 5 Campsite Designations	
Odd	Even	Odd	Even
L74.7	R74.9	L 94.9	L 95.8
R76.4	R82.6	L 96.5	L 99.1
R84.0	L84.4	R 99.1	R102.9
L85.7	L91.1	R103.1	R103.8
L92.2	R93.9	R105.6	R108.2

Table 10. Day 4 and Day 5 campsite selections for large groups.

Campsite Designation	Campsite Name	Campsite Capacity	Odd	Even
		DAY 4		
L 73.4	(Unnamed)	40	A[a]	
R 73.9	(Unnamed)	40	A	
R 74.0	74 Mile	40		A
R 75.5	Nevills Rapids	40	B	
L 76.5	Hance Rapids	40		B
L 81.1	Grapevine	40	C	
L 87.1	Last Chance	40		C
		DAY 5		
R 89.3	(Unnamed)	40	A (4)[b]	
L 93.3[c]	Lower Granite Rapids	40	B (4)	A (5)[c]
L 99.5	100 Mile	40		B (6)
R107.5	(Unnamed)	40	C (6)	
L107.7	(Unnamed)	40	C (6)	
R107.9	Bass Rapids	40		C (5)
R108.3	Lower Bass	40		C (5)
R109.3	(Unnamed)	40		C (5)

[a]Day 4-group A should camp at Day 5-group A site; Day 4-group B should camp at Day 5-group B site; Day 4-group C should camp at Day 5-group C site.

[b]Numbers in parentheses are hours of float time from previous night's campsite.

[c]Not to be used by irregular trips.

mutually make other prior firm arrangements. The letters A, B, and C indicate the ordered patterns. In the interpretation of the tables, it should be remembered that the "odd" pattern for Day 4 concatenates with the "even" pattern for Day 5 and vice versa. If other arrangements were not made, each of the groups can still count on an available campsite and can plan its schedule for the day accordingly. Regular and irregular trips can potentially come into conflict only for campsite L93.3. For this campsite, the regular trip has a priori priority; e.g., irregular trips may not occupy the campsite even if it is vacant at the time of arrival unless specific prior arrangements were made with the regular trips of that day. The issue would be of importance in the unusual situation that a full complement of regular trips and three large irregular trips occupy the river stretch simultaneously. Should this problem occur, at least one of the three 30-capacity campsites--R93.2, L95.9, and R106.8--would be unoccupied and could be used in this extenuating circumstance. If enough time is left in the day, at least three of the five 40-capacity campsites--R107.5, L107.7, R107.9, R108.3, and R109.3--would be unoccupied.

The scheduling is not as critical for the one medium-sized group. The letters A and B for the patterns shown in Table 11 refer to options and are patterned thus to balance the use of campsites.

Day 6.--The sixth day's scheduling is uncomplicated--camp after mile 110 and before mile 138. The Day 5 section must be cleared for groups following by 1 day and groups preceding by a day will be occupying campsites beyond mile 138. A critical point occurs in the stretch. Deubendorff Rapid at about mile 132 is well known as a hinderance at low water, which occurs during the morning and early afternoon. Trips must often wait for high enough flows to be

Table 11. Day 4 and Day 5 campsite selections for medium groups.

Campsite Designation	Campsite Name	Campsite Capacity	Odd	Even
		DAY 4		
L 73.7	(Unnamed)	20	A[a]	
L 74.2	(Unnamed)	20	A	
R 74.3	(Unnamed)	30		A
L 77.1	(Unnamed)	20	B	
L 78.8	Sockdolager Rapids	30		B
		DAY 5		
R 91.2	91 Mile Creek	25	A (4.0)[b]	
R 91.5	Trinity Creek	20		A (4.1)
R 93.2	Upper Granite Rapids	30	B (3.8)	
L 95.9	96 Mile	30		B (4.1)
R106.8	107 Mile	30		B (6.7)

[a]Day 4-group A should camp at Day 5-group A site; Day 4-group B should camp at Day 5-group B site; Day 4-group C should camp at Day 5-group C site.

[b]Numbers in parentheses are hours of float time from previous night's campsite.

able to progress and at times a 1- or 2-day wait has been required. For this reason, trips should not routinely plan to camp within a few miles upriver of the rapid since these campsites may be occupied by trips delayed by low water.

Day 7 and Day 8.--On the seventh and eighth days, transit is made through the Muav Gorge section. The problem in scheduling is similar to that in Granite Gorge and the manner of scheduling is the same. In Table 12, the patterns for the small and medium groups are shown. A number of alternatives exist so that, of these campsites, specific selections are up to the boatmen for the 2 days. For the three large groups, order is important because of the lack of alternatives and the generally long float times involved. The patterns are shown in Table 13.

Day 9.--The only special requirement for the ninth day is that all trips must pass mile 175 in order to clear the Day 8 stretch for following trips. Numerous campsites exist from mile 175 downriver so campsite selection is in control of the boatmen.

Day 10.--On the tenth day, the only special restriction is not to pass mile 207 because campsite occupancy conflicts with trips for the preceding day would occur.

Day 11.--The eleventh camp is the last one involved in scheduling. On the twelfth day, exit will be made from the system at Diamond Creek or at mile 240. Special scheduling is not needed for the small and medium groups; six small and seven medium campsites exist within range of mile 240

Table 12. Day 7 and Day 8 scheduling patterns for small and medium groups.

Campsite Designation	Campsite Name	Campsite Capacity	Odd	Even
		DAY 7		
L139.4	(Unnamed)	20	M	
L139.9	Lower 140 Mile Canyon	35		M
L143.3	Kanab Rapids	30	SM	
L148.3	Matkatamiba Canyon	10	S	
R149.8	Upset Rapids	15		S
L152.3	(Unnamed)	25		SM
L153.8	Sinyala Rapids Ledge	30		M
R155.6	(Unnamed)	25	M	
		DAY 8		
R158.1	Cork Springs	15		S
R158.6	(Unnamed)	30		M
R160.7	(Unnamed)	15	S	
L163.9	164 Mile Creek	30	M	
L169.3	(Unnamed)	12		S
L169.9	(Unnamed)	10	S	
R170.9	(Unnamed)	25		M
R171.1	Stairway Canyon	20	M	
L171.4	Mohawk Canyon	25		M
L172.1	(Unnamed)	20	M	

Table 13. Day 7 and Day 8 scheduling patterns for large groups.

Campsite Designation	Campsite Name	Campsite Capacity	Odd	Even
		DAY 7		
L138.5	138-1/2 Mile	40	A[a]	
R138.9	Fishtail Rapids	40		A
R139.4	(Unnamed)	40	B	
L139.7	Upper 140 Mile Canyon	40		B
L145.4	Olo Canyon	40	C	
R151.6	Art's Ledge	40		C
		DAY 8		
L159.8	(Unnamed)	40		A (5)[b]
R164.5	Tuckup Canyon	40	A (6)	
L166.5	Upper National Canyon	40		B (6)
L166.6	Lower National Canyon	40		B (6)[c]
R168.1	Fern Glen	40	B (7)	
L172.8	(Unnamed)	40		C (7)
R174.2	Upper Cove Canyon	40	C (5)	
R174.3	Middle Cove Canyon	40	C (5)[d]	

[a]Day 7-group A should camp at Day 8-group A site; Day 7-group B should camp at Day 8-group B site; Day 7-group C should camp at Day 8-group C site.

[b]Numbers in parentheses are hours of float time from previous night's campsite.

[c]Alternate to campsite L166.5; not to be used simultaneously.

[d]Alternate to campsite R174.3; not to be used simultaneously.

and a greater number yet within range of Diamond Creek. For large groups, nine campsites are in comfortable range of Diamond Creek and six are in range of mile 240. Table 14 shows the schedule pattern for the large groups. To insure that all trips can exit the system on Day 12, whether it be from Diamond Creek or mile 240, trips that will terminate at Diamond Creek should camp at or before R219.7. Campsites closer to Diamond Creek could be used if it were known by the boatmen that only one or none of the trips were preceding past Diamond Creek. Trips exiting at mile 240 must be given priority for campsites below R219.7 in order to be able to pass mile 240 on the twelfth day.

Undercapacity Scheduling

Operation of the system under its full capacity is of two types. First, one or more groups have less than the full complement of people and, second, there are less than five groups departing in a day. Undercapacity, as combinations of the two types, can be expected to commonly occur and scheduling must be able to conveniently accommodate it. This is the topic that will be developed in the following.

For five trips departing on a day, at least one must be an S-group, and at least three must be L-groups. Technically, one S-group must be included only on odd dates but this will be covered shortly. Any combination of one to five small groups, zero to four medium groups, and zero to three large groups totaling five or less could be accommodated in the system by letting small groups camp at small, medium, and large campsites, and medium groups camp at medium and large campsites. For even-date departures, the above combinations can be extended to cover combinations of zero to five small groups, zero to five medium groups, and zero to three large groups.

Table 14. Day 11 scheduling patterns for large groups.

Campsite Designation	Campsite Name	Campsite Capacity	Odd	Even
L207.6	(Unnamed)	40	A[a]	
L208.8	Granite Park	40		A
R211.6	Fall Canyon	40	A	
L212.9	Pumpkin Spring	40		A
R219.1	Trail Canyon	40	A	
R219.7	Upper 220 Mile Canyon	40		A
R219.9	Lower 220 Mile Canyon	40	B	
L222.0	222 Mile Creek	40		B
L222.1 (Diamond Creek)	(Unnamed)	40	B	
L238.5	Bridge Canyon Hotel	40		B

[a]A = campsites for exit at Diamond Creek or mile 240; B = campsites for exit at mile 240 only.

The existing patterns have been developed to balance campsite use and spatially distribute groups as evenly as possible over campsites. To take advantage of these features and to avoid adding another whole set of patterns, the existing patterns will be used. They can be used simply by appropriately assigning S, M, or L labels to the groups. That means a group assigned an S label will follow S patterns, etc. Considering all schedule patterns, there are a minimum of two M patterns, three L patterns, and two S patterns for odd-date departures or one S pattern for even-date departures. Table 15 shows assignments for all combinations of group sizes and schedule patterns. For an example, suppose on a day, two groups of 8, two groups of 20, and one group of 40 are to depart. They would be labeled according to combination seven in Table 15 as follows: one each of the small groups would be labeled as S and M, one each of the medium groups would be labeled as M and L, and the large group would be labeled as L. The groups would each follow the labeled pattern where patterned scheduling is necessary. The combination applies for either odd or even departure dates. In practice, the table would not have to be used at all because once the idea is perceived, pattern assignments become quite easy to define.

Now consider undercapacity scheduling resulting from less than five trips departing in a day. This problem can be solved to include undercapacity group sizes as well. The solution is very simple using Table 15. Pick an appropriate pattern assignment including the sizes of the fewer than five groups that are to be scheduled, and then select the pattern assignments for only these groups. For example, say two small, one medium, and one large group are to be scheduled for an even-date departure. From Table 15, any one of combinations 6, 7, and 10 would do, say number 7. Select the assignments S and M for the

Table 15. Pattern assignments for undercapacity scheduling.

Combination	Number of Persons in a Group					
	8 or Less		9 to 21		21 to 40	
	No. of Groups	Pattern Assignment	No. of Groups	Pattern Assignment	No. of Groups	Pattern Assignment
			ODD OR EVEN DAYS			
1	1	S	1	M	3	L,L,L
2	1	S	2	M,L	2	L,L
3	1	S	3	M,L,L	1	L
4	1	S	4	M,L,L,L	0	
5	2	S,M	0		3	L,L,L
6	2	S,M	1	L	2	L,L
7	2	S,M	2	L,L	1	L
8	2	S,M	3	L,L,L	0	
9	3	S,M,L	0		2	L,L
10	3	S,M,L	1	L	1	L
11	3	S,M,L	2	L,L	0	
12	4	S,M,L,L	0		1	L
13	4	S,M,L,L	1	L	0	
14	5	S,M,L,L,L	0		0	

Table 15.--Continued.

Combination	Number of Persons in a Group					
	8 or Less		9 to 21		21 to 40	
	No. of Groups	Pattern Assignment	No. of Groups	Pattern Assignment	No. of Groups	Pattern Assignment
			ODD DAYS ONLY			
15	0		2	M,M	3	L,L,L
16	0		3	M,M,L	2	L,L
17	0		4	M,M,L,L	1	L
18	0		5	M,M,L,L,L	0	
19	1	M	1	M	3	L,L,L
20	1	M	2	M,L	2	L,L
21	1	M	3	M,L,L	1	L
22	1	M	4	M,L,L,L	0	
23	2	M,M	0		3	L,L,L
24	3	M,M	0		2	L,L
25	4	M,M,L,L	0		1	L
26	5	M,M,L,L,L	0		0	
27	2	S,S	0		3	L,L,L
28	3	S,S,L	0		2	L,L
29	4	S,S,L,L	0		1	L
30	5	S,S,L,L,L	0		0	

small groups, L for the medium group, and L for the large group. The groups would then adhere to the corresponding patterns. As before, the table does not have to be used because of the simplicity of pattern selection.

Overcapacity Scheduling

Overcapacity use must be limited to occasional unavoidable situations; it must never be considered as part of routine system use. Unavoidable circumstances will occur, however, and they must be managed to the satisfaction of all users if at all possible. One type of overcapacity is that of more people in a group than the maximum. The other type is more groups than the maximum number allowed in a departure day.

There is no substantiable justification in saying a campsite rated at a given capacity cannot be used for a greater number. Campsite capacities are estimates arrived at by an evaluation procedure, as contrasted to designed capacities. They represent the number of occupants beyond which the campsite should not routinely be used and beyond which even a moderate increase, say 20 percent, would likely cause uncomfortable crowding and lack of privacy. For this reason, occasional small overages in group sizes could be tolerated without scheduling changes. Habitual offenders must be firmly discouraged under threat of enforceable curtailment of use.

If the group size for the small or medium groups were exceeded by a number too great to overlook, say by more than five, then the offending group would be classed at the next larger size. For example, a small group would be reclassed as a medium group. One of three possible results could occur: two M and three L groups, one M and four L groups, or five L groups. The cases all have the

same resolution. Fit the groups in excess of one M and three L groups into alternate campsites beyond mile 20 if possible, or into proper capacity campsites for the alternate date schedule. Thereafter, for the remainder of the trip, the excess groups would be designated as irregular trips even though they may follow a regular schedule. The only sacrifice in this scheme would be the lack of mutual privacy for groups using L7.9 and R7.9.

Now suppose the number of groups is greater than five. The non-offending five groups would follow the routine schedule and the offending groups would be treated as above.

Scheduling Evaluation Considerations

The daily carrying capacity of three 40-person groups, one 20-person group, and one 8-person group is justified by the scheduling evaluation. This capacity can be scheduled for regular 12-day trips as well as for irregular trips, but the small number of campsites in certain river sections requires well-understood scheduling patterns to be followed. Boatmen must know specifically where a number of campsites are located and their capacities. A map containing this information, similar to a Belknap (1966) River Guide, would solve this problem. Regular trip boatmen must also be aware of the general upriver or downriver locations and campsite selection plans of other trips that departed on the same day.

Scheduling is not influenced by undercapacity use in that the full-capacity scheduling system applies. Similarly, overcapacity scheduling fits comfortably in the full-capacity scheduling system.

Regarding simplicity and flexibility, the scheduling system is about midway between the extremes of complete laissez faire and complete rigidity. In 5 of the 11 camping sections, laissez faire is essentially the rule for all groups. In the other 6, laissez faire is essentially the rule for some groups in some sections. In all of the 6 pattern-scheduled camping sections, almost complete rigidity applies to the three large groups. Even so, the rules for campsite selection are simple to apply and the inflexibility does not conflict with normal progress downriver or ancillary recreational activities. To further clarify, users would not likely recognize the existence of restrictions on the day's activities in the pattern-scheduled river sections unless the boatmen made it an issue.

In Table 16, the scheduling evaluation results are summarized and condensed. For each day of regular trips, acceptable downriver progress in the neighborhood of 20 miles can be made each day. Generally, there are an adequate number of attractions in each section and these do not include interpretive stops such as for geologic or ecological interpretations, nor are other activity stops included, such as for swimming or just plain loafing. It must be concluded, however, that attractions are not so abundant as to preclude the possibility of overuse considering an average of five groups per day are potential users.

There appear to be no serious restrictions on irregular trips if they average only one or two departures per day. More than an average of two can be accommodated but with the penalty that with greater numbers, they must conform more to regular patterns.

Finally, the carrying capacity can be increased if this scheduling system were to be put into practice. The odd-even date scheduling allows a group of size 20 to be

trips.

Day or Campsite Section	Regular Trip Camping Range Limits by Day[a]			Upper Bounds for Irregular Trips for Campsite Sections				No. of Attractions in Ranges[c]
	Lower	Upper[b]	Footnote Nos.	No. of L	No. of M	No. of S	Footnote Nos.	
1	7.0	*[d]	e,f,g	3	1	1	h	11
2	25.0	68.0		*	*	*		
3	*	72.1		*	*	*		4
4	73.4	87.1	i,e,f	3	2	4	e,g	5
5	89.3	109.3	e,f	2	2	4	e,g	8
6	112.5	138.3		*	*	*		6
7	138.5	152.3	e,f,g	3	2	2	e,g,f	2
8	153.8	174.3	e,f,g	3	3	2	e	5
9	175.8	194.0		*	*	*		2
10	*	207.2		*	*	*		1
11	207.6	238.5	e	5	*	*	e	7
12	> 238.5	*						

[a] Mile numbers set by campsite locations.

[b] Upper bounds for regular trips are L = 3, M = 1, and S = 1.

[c] Taken from Table 5.

[d] An asterisk indicates locally unrestricted.

[e] L groups must follow a schedule pattern.

[f] M groups must follow a schedule pattern.

[g] S groups must follow a schedule pattern.

[h] Number of regular plus irregular trips are L = 3, M = 1, and S = 1.

[i] The limit for S groups is 93.9.

scheduled on odd dates instead of a group of size 8. The patterns of assignment that apply are given as combinations 15 through 18 in Table 15. The result is that on odd days the total number of users departing would be 160, and on even dates, 148. The average per day becomes 152, for an increase of 2.7 percent in the carrying capacity.

Non-Recreational Trips

Trips for other than recreational purposes fall mainly into the categories of patrol, monitoring, maintenance, research, education, training, and management. Whatever the purposes of non-recreational trips, they would come under the umbrella of the scheduling system and all personnel would be counted as users. Such trips would be entered in the scheduling system in the same general way as for recreational trips whenever possible. In cases where a non-recreational trip cannot adhere to the normal procedures for scheduling a departure date and timeliness is important, it would be scheduled as an overcapacity trip as described earlier. To accomplish their objectives, most of the non-recreational trips would not be able to follow the regular schedule and would therefore be assigned to the irregular status.

Off-Season Use

The season has more or less arbitrarily been set as 182 departure days. Strong demand for river trips is unlikely to develop outside the spring-summer-fall period covered by the 182 days. Running the river in the off-season is more difficult and dangerous than during the season. Low air and water temperatures, adverse weather,

and low water flows, as well as the absence of other nearby groups for safety and rescue considerations, make trips slow, difficult, and somewhat dangerous. If the support costs to the NPS are nominal or recoverable, and if the NPS is not placed in a prohibitive liability position, off-season trips should be allowed. Such trips need not follow the scheduling system used during the season, but should be allowed essentially complete self-scheduling freedom. Count should be kept of the user days and number of trips under an off-season use category, but should not necessarily be counted against concessionnaire allotments, private trip allotments, or carrying capacity limits. Use should be counted against the denoted limits if user impacts on the campsites and the environment are equivalent to or greater than similar impacts during the season.

Because of the low air temperatures, in contrast to the very high temperatures during the season, and becuase of low water flows, as well as the absence of other trips, the best time for maintenance and restoration of campsites may well be during the off-season.

Allotments and Contracts

Total user-days per season is not an appropriate way of assigning specific allotments. Total user-days for a season, or monthly for that matter, are useful only for overall comparative purposes among different categories of users; e.g., recreational versus non-recreational users. The basis for the carrying capacity is the number and size of groups departing daily and allotments must take into account these features. Allotments defined by days would be too cumbersome and would complicate allotment assignment by forcing departure scheduling upon it. Weekly

allotments are more reasonable. To build some further flexibility into allotments, a small part of a total allotment could be free of time limitations so that it could be used for unfilled reservations. These two parts will be labeled first-priority and second-priority allotments. First-priority allotments will be given first preference in reservations for all allotments. After all first-priority allotments have been accommodated, the second-priority allotments can be considered to fill remaining reservation openings. A first-priority allotment must specify the number and size of groups for each week, whereas the second-priority allotment specifies the number and size of groups but not the week.

Prior to the development of contracts with concessionnaires, the carrying capacity must be partitioned into major categories. These categories are recreation, support, discretionary other management, and reserve. The two components of the recreation category are concessionnaire and non-concessionnaire, or private. The support category includes monitoring, maintenance, NPS-sponsored education and training, and supportive research. The discretionary category allows for use assigned at the discretion of the NPS, of which some should be for the investigation of innovations, new equipment and procedures, etc. In this category fall research trips for purposes other than direct support of river-running. The other management category covers use for park management that is not directly related to river-running; for example, back-country management. The reserve category is that part of the carrying capacity to be held in reserve for assignment as unpredictable needs arise during the season but mostly for planned non-use. Allotments in these categories would be made according to first and second priorities.

The recreation category allotments present a special case. First, the assignment of the recreation allotment between the concessionnaire and non-concessionnaire components must be made. Then, the concessionnaire allotments must be partitioned among the concessionnaires.

It is assumed that the usual procedure of advertising a request for proposals (RFP) would be followed. Comprehensive background material would be distributed, including information concerning capacities, scheduling, etc. as found in this report. Proposal requirements, in addition to the various ones not in the scope of this project, would be the proposed (1) first- and second-priority allotments, (2) specification of regular and irregular trips, (3) durations for irregular trips, (4) number and qualifications of support personnel (boatmen, helpers, interpreters, etc.) for typical and special trips, (5) anticipated attractions to be visited and activities, (6) time required for provisioning and rigging at Lees Ferry, and (7) embarkation times.

Criteria for evaluating proposals established prior to and distributed with the RFP supporting materials would be used in two steps. Step one would be the selection of proposals qualifying for consideration for contracts. Step two would be the critical evaluation and ranking of qualified proposals for contract consideration. At this stage, the proposed first-priority trips, aggregated over all of these proposals and other allotments by week and group size, would be evaluated in relation to the carrying capacity for a week. For emphasis, the aggregation must include all other allotments, including those assigned by the NPS for non-concessionnaire subscription. Over- and undercapacity weeks would be flagged for negotiation in formulating the specifics of contracts. Negotiations covering these and the other proposal aspects would be done

according to the ranked order of step two. The result would be to specify the allotment for each concessionnaire and to alleviate over- and undercapacity imbalances. During these negotiations, the second-priority allotment can be specified as a percentage of the first-priority allotment. The allotments must be subject to annual renegotiation based on performance criteria such as the ability to adhere to allotment specifications, schedules, and departure times to mention a few.

Operations, Monitoring, and Maintenance

Only the highlights of operations will be covered. Assignment of allotments must take place at or near the end of a season to allow time for concessionnaires to plan for the following season. After allotment assignments have been completed, a final date must be set for first-priority allotment reservations to be made. After that date, second-priority allotment reservations would be made. Reservations for non-concessionnaire first-priority and second-priority allotments would be made by the NPS to hold openings for these anticipated trips and for reservations assigned to specific private trips upon request.

On each departure day, the NPS Ranger assists and directs in campsite selection for the departures of the day. It would be the responsibility of the boatmen to understand and be able to apply the scheduling system after the first day. To help in this, it is strongly recommended that a campsite guide be published that would give the pertinent scheduling and campsite information. Furthermore, it is recommended that trip tickets be used by boatmen to indicate the specific campsites used on each day and site visitations. The trip tickets would assist in monitoring

the system for possible overcapacity situations, in refining the scheduling system, and in adjusting the carrying capacity.

Monitoring the system is of vital importance. Monitoring must be budgeted and scheduled for periodic trips, say at least once every other week. Two forms of monitoring should be planned. One form, much like patrolling, would involve inspection of selected campsites and attractions to detect signs of degradation and maintenance needs. The selection of sites to be inspected would be made on the basis of intensity of use within and outside the critical river sections, although the overall heaviest use will be in the critical sections. The second form of monitoring, one requiring only a few trips per season for a predetermined set of sites, would focus on measuring impact from use and changes caused by environmental factors such as campsite erosion by wind and water.

Monitoring is important as the feedback link for the adjustment of carrying capacity, the scheduling of maintenance, and the modification of scheduling patterns.

Maintenance is limited to procedures for which the results are consistent with the wilderness aspects of the environment. Cosmetic improvements by removal of litter, cleaning up of firesites, etc. are unquestionably maintenance tasks. Campsite modification by structural development to guard against erosion or correct its effects may be a questionable maintenance procedure. Appropriate maintenance provides the means for counteracting impacts that lead to decreasing the carrying capacity.

Integration with Motor-Powered Trips

The present use is dominated by motor-powered trips that average 35 miles per day. The carrying capacity, which exceeds present total use levels, and the scheduling system can be implemented now or at any future time. If it were implemented now, the motor-powered trips can be conveniently accommodated until they are phased out. The scheduling system applies in all given aspects except for the motor-powered trip variants as follows. Motor-powered trips will adhere to all scheduling guidelines except the trips will be of 8 days' duration instead of 12 and camping will be done according to the following pattern (refer to Table 16):

Day 1 - Camp in campsite section 1
Day 2 - Camp in campsite sections 2 or 3
Day 3 - Camp in campsite sections 4 or 5
Day 4 - Camp in campsite sections 6 or 7
Day 5 - Camp in campsite sections 8 or 9
Day 6 - Camp in campsite section 11
Day 7 - Camp in campsite sections 11 or 12
Day 8 - Camp in campsite section 12

Campsites will be selected according to the schedule for the specific campsite section, group size, and odd- or even-date. Priority of campsite selection will be given to non-motorized trips in each pattern-scheduled campsite section.

Summary: The User Carrying Capacity

On the merit of the attributes of the Grand Canyon and the Colorado River, the policy for river-running recreation was defined to be: float trips on the Colorado River in the Grand Canyon region will be conducted to allow a broad spectrum of people to participate in an adventuresome,

aesthetically outstanding wilderness experience of long duration. The policy was expanded to focus on the health, well-being, and safety of users; the nature of the activity; the interpretation of the resource; and maintenance of the environment. The carrying capacity determination was made on the basis of the policy statements. The following parameters were used:

1. season = 182 days (May-October),
2. largest possible group = 40 users,
3. intergroup spacing on the river = 3 miles,
4. average daily float time = 5 hours,
5. river flow rate = 4.2 miles per hour,
6. average daily float distance = 21 miles, and
7. regular trip duration = 12 days.

Constraints imposed by campsite capacities and locations limited the number and sizes of groups departing daily to one group of 8 persons maximum, one group of 20 persons maximum, and three groups of 40 persons maximum. A scheduling system was developed that would allow the full complement of trips to depart each day of the season. The upper bound on the carrying capacity was thereupon determined to be:

1. five trips departing daily, i.e., one group of 8 persons maximum, one group of 20 persons maximum, and three groups of 40 persons maximum;
2. a daily departure capacity of 148 persons;
3. a seasonal capacity of 26,936 persons; and
4. a seasonal carrying capacity of 296,296 user-days.

Allotments must be assigned primarily on the basis of the number of trips, size of groups, and week of departure, but usage can be compared on the basis of user-days.

The carrying capacity and scheduling system can be installed at any time because it can accommodate motor-powered trips as well as non-motor-powered trips.

Recommendations

Substantiation for and expansion on recommendations is not reproduced here, but can be found in the body of the report.

It is recommended that:

1. The general policy, "float trips on the Colorado River in the Grand Canyon region will be conducted to allow a broad spectrum of people to participate in an adventuresome, aesthetically outstanding wilderness experience of long duration," be adopted literally or in principle.

2. Specific policy statements, such as those presented in this report, governing the health, well-being, and safety of users; the nature of the activity; the interpretation of the resource; and the maintenance of the environment be formally enunciated.

3. A management plan be developed on the basis of the policy statements, but within the physical, environmental, sociological, and operational constraints operative in the system.

4. A part of the management plan be a scheduling system to maintain use within the constraints and to avoid severe localized and time-related stresses in the system.

5. The scheduling system defined in this report be implemented.

6. The carrying capacity be declared to be 296,296 user-days subject to the following conditions for planned use: (a) five trips maximum departures per day for 182 departure days (May-October) composed of one group of 8 users maximum, one group of 20 users maximum, and three groups of 40 users maximum; (b) routine trips of 12 days' duration from Lees Ferry to Separation Canyon; and (c) scheduled campsite selection in campsite deficient sections of the river.

7. Carrying capacity be reduced, if necessary, to meet other constraints such as environmental and sociological ones in any of the following ways: (a) reduce the number of departure days, (b) reduce the group sizes, and (c) reduce the number of groups per departure day.

8. Allotments for use be established on the basis of the number of trips and the size of groups for each week in the season.

9. Contracts with concessionnaires specify the number of trips and the size of groups for each week of the season and be included in particulars subject to annual renegotiation.

10. Monitoring and maintenance programs be developed and budgeted.

11. River-runners' campsite and attraction guide be published for use by boatmen in the daily campsite selection according to the scheduling system.

12. Trip-log tickets be used to support the monitoring of the system.

13. The scheduling system and operational requirements, augmented by the reasoning behind their implementation be communicated to concessionnaire personnel and other users and the public by educational meetings and user-oriented documentation.

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